Angular dependence of critical currents in YBCO coated conductors and thin films

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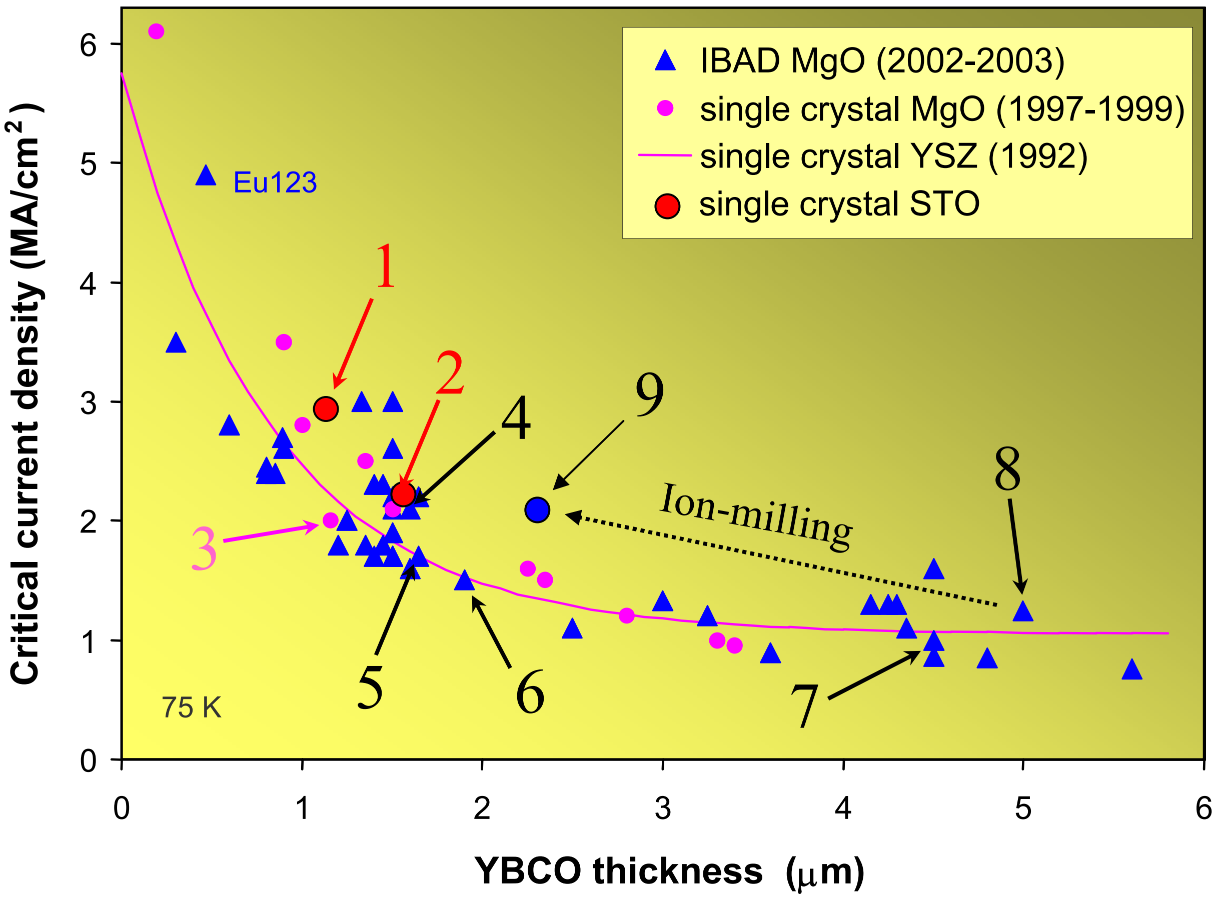
The J_c of PLD YBCO films on polycrystalline Ni-alloy using IBAD MgO is equivalent to that of films on single-crystal substrates (at 75K, self field)



Implication:

- J_c limited by bulk vortex pinning
- Uniform current flow

as opposed to

- J_c limited by weak links
- Percolative paths
- Non uniform current flow

What happens as a function of temperature and magnetic field ?

What can we learn from the field, angular and temperature dependence of J_c?

•Immediate goals:

✓Identification of pinning sources (correlated vs. uncorrelated defects, etc)
✓Comparison of CC made by different routes and films on single crystals
Are pinning mechanisms the same ?
(High quality CC available from various sources)

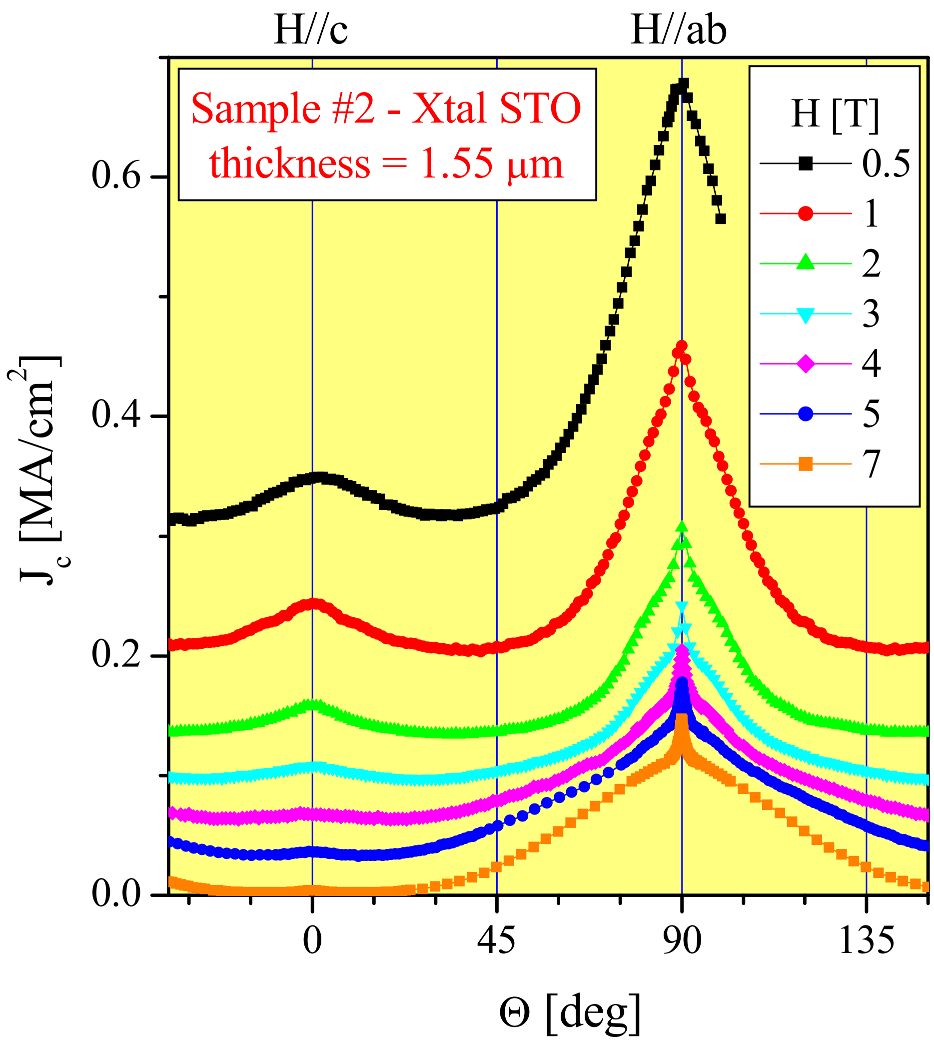
•Long term goals:

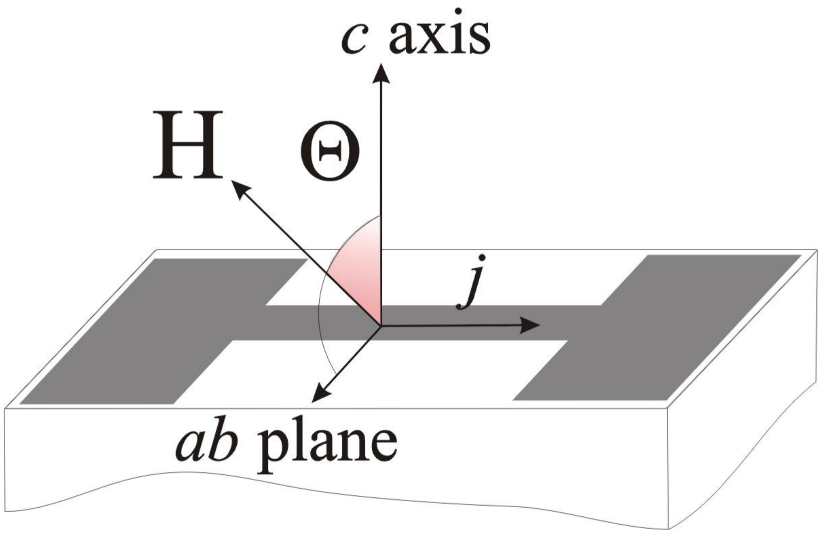
Can we improve in-field J_c by appropriate engineering of defects ?

•Questions:

✓How reproducible is $J_c(H,\Theta)$ for a given fabrication process ?
✓What is a "standard" or "reference" sample ?
✓Which are the useful characterization parameters ?

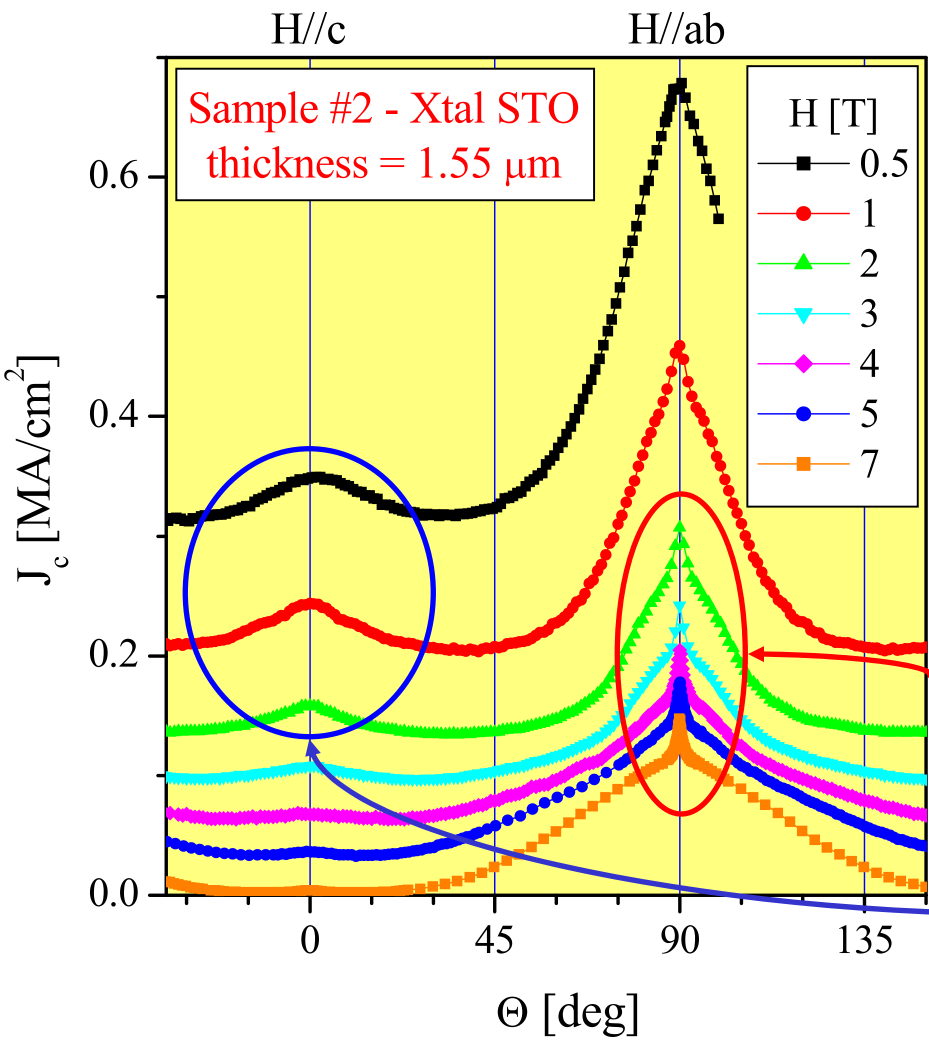
Measurements of the angular dependence of J_c





Measurements at T = 75.5 K unless otherwise indicated

The angular dependence of J_c arises from a combination of factors and exhibits various regimes



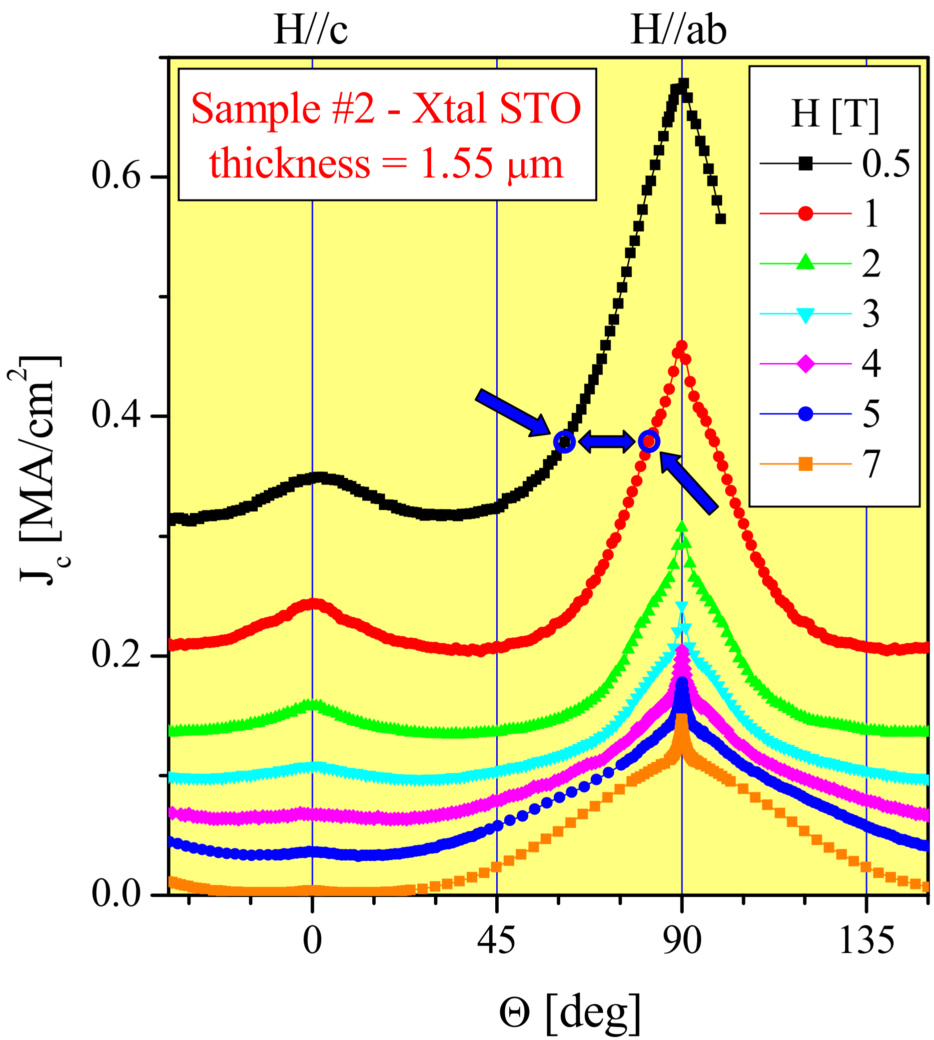
Uncorrelated disorder (random defects) + Electronic mass anisotropy → Smooth $J_c(\Theta)$ maximum at H//ab

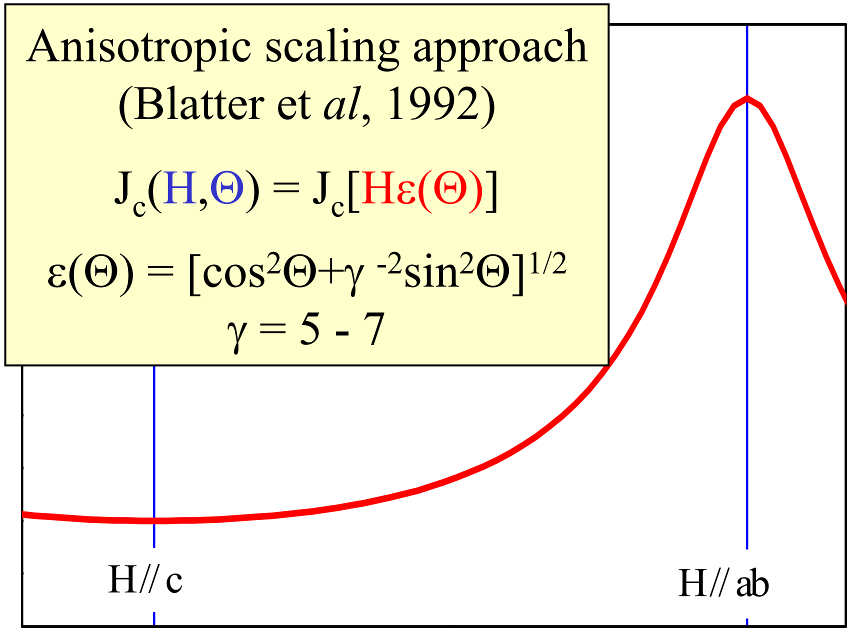
Correlated disorder (extended parallel defects, linear or planar) → Additional peaks

ab plane:
- intrinsic pinning
- laminar structures ?

c axis
- twin boundaries
- grain boundaries (dislocations)

Pinning by uncorrelated disorder (random defects): influence of electronic mass anisotropy





Anisotropic scaling approach
(Blatter et *al*, 1992)

$J_c(H,\Theta) = J_c[H\varepsilon(\Theta)]$

$\varepsilon(\Theta) = [\cos^2\Theta+\gamma^{-2}\sin^2\Theta]^{1/2}$

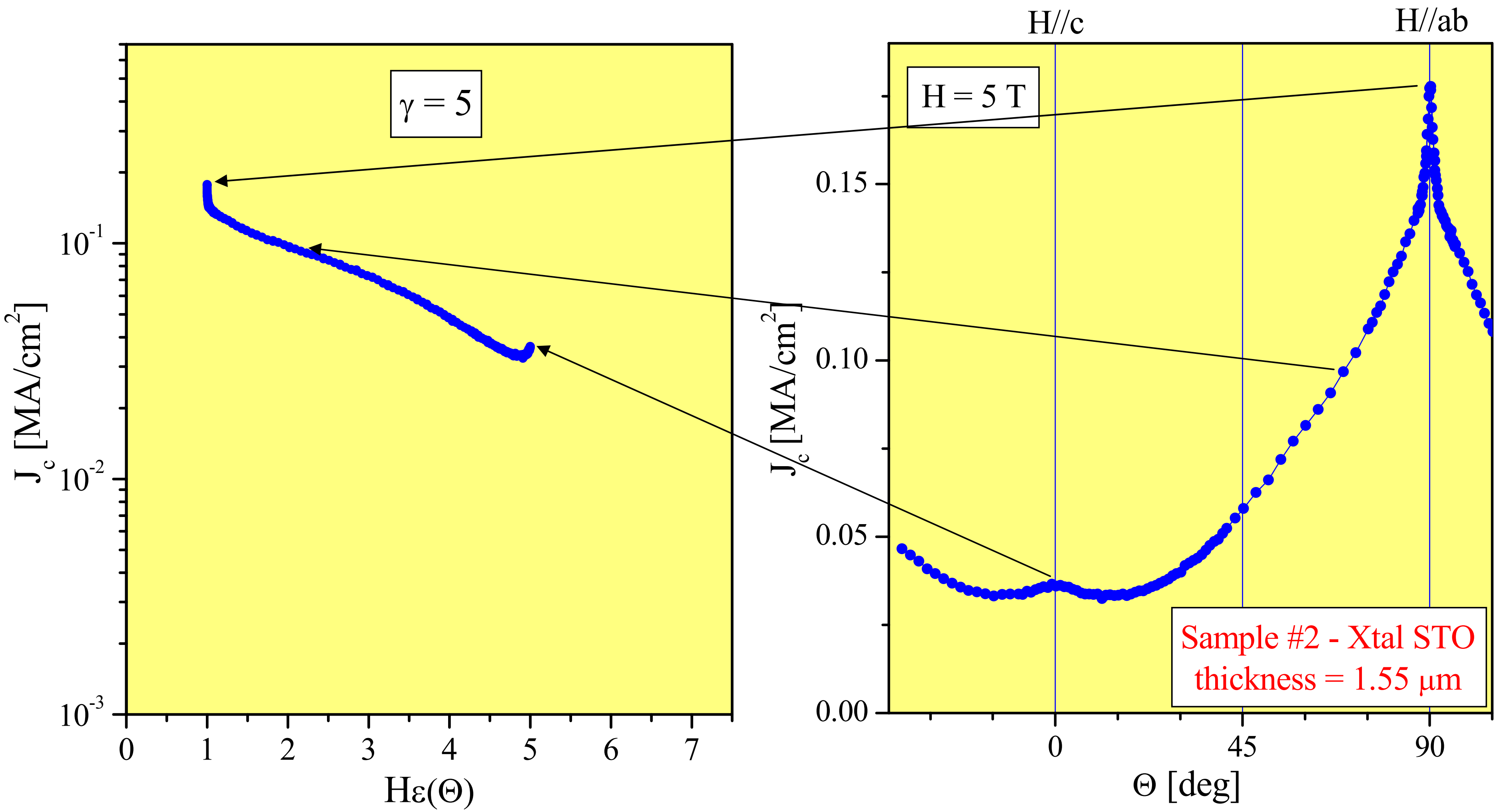
$\gamma = 5 - 7$

H [T]	Θ	Hε(Θ)
0.5	63°	0.24
1	82°	0.24

Same J_c ?

YES !

Contribution of the uncorrelated disorder to J_c



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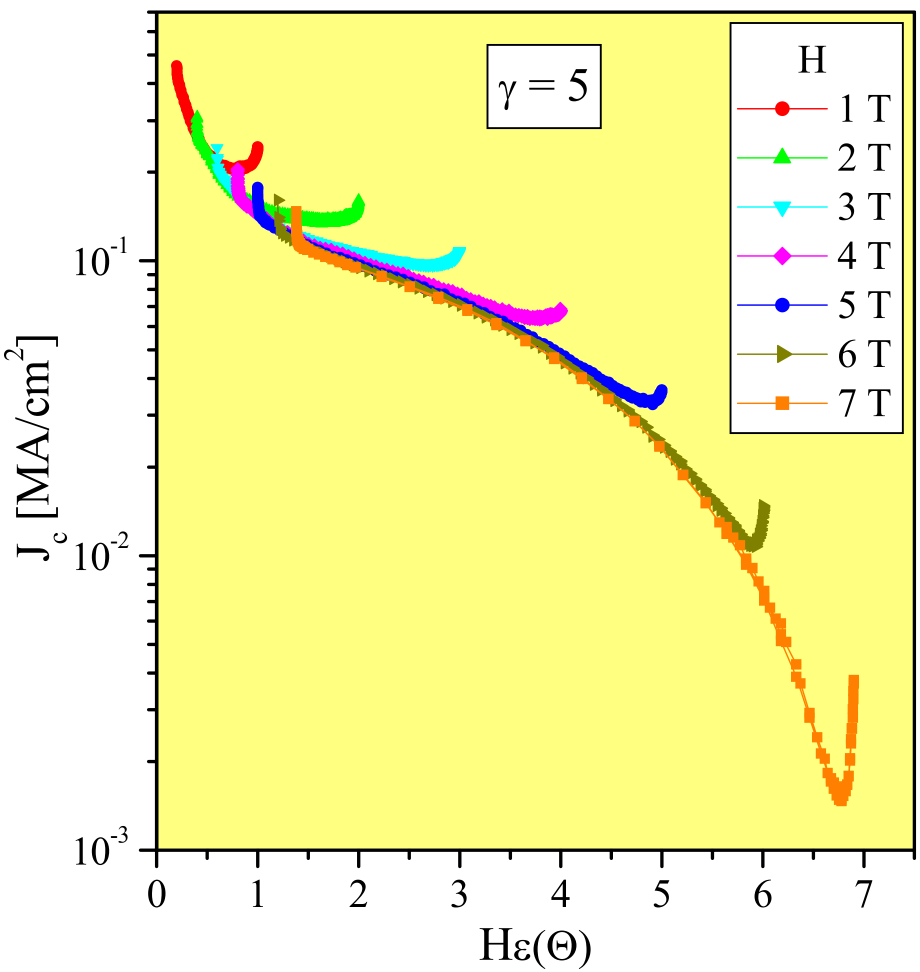

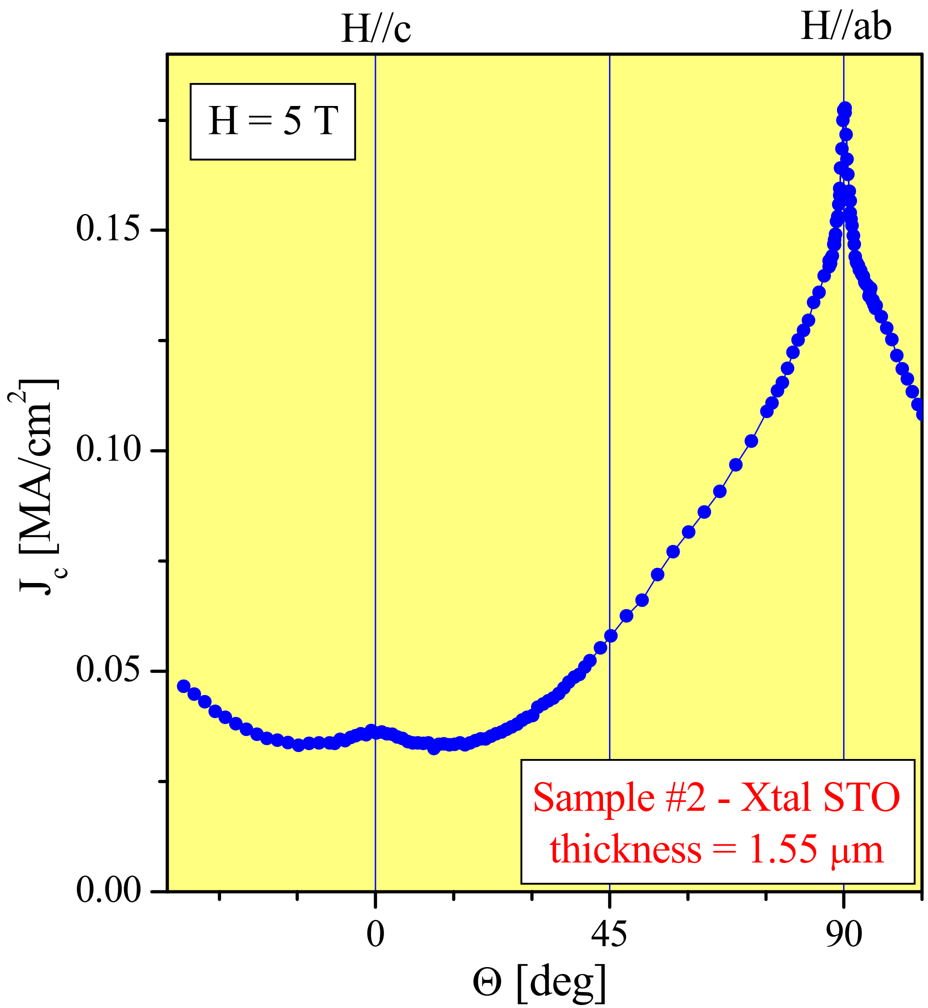

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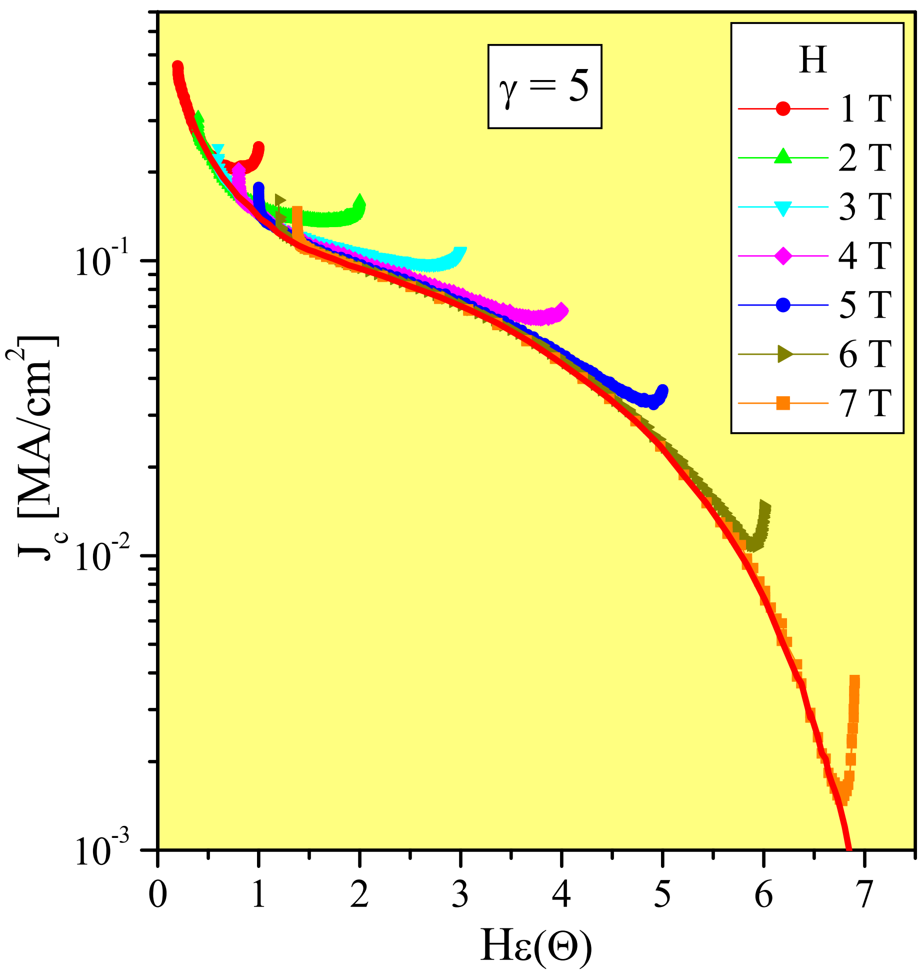
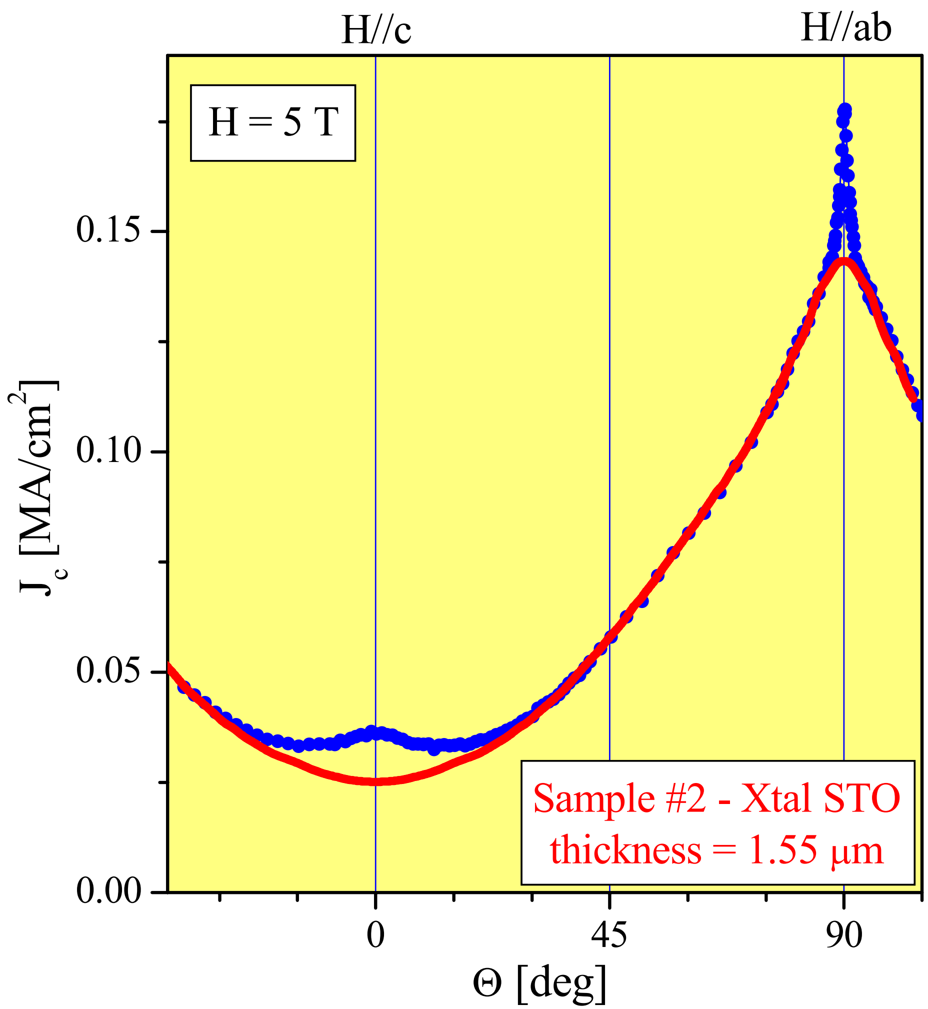
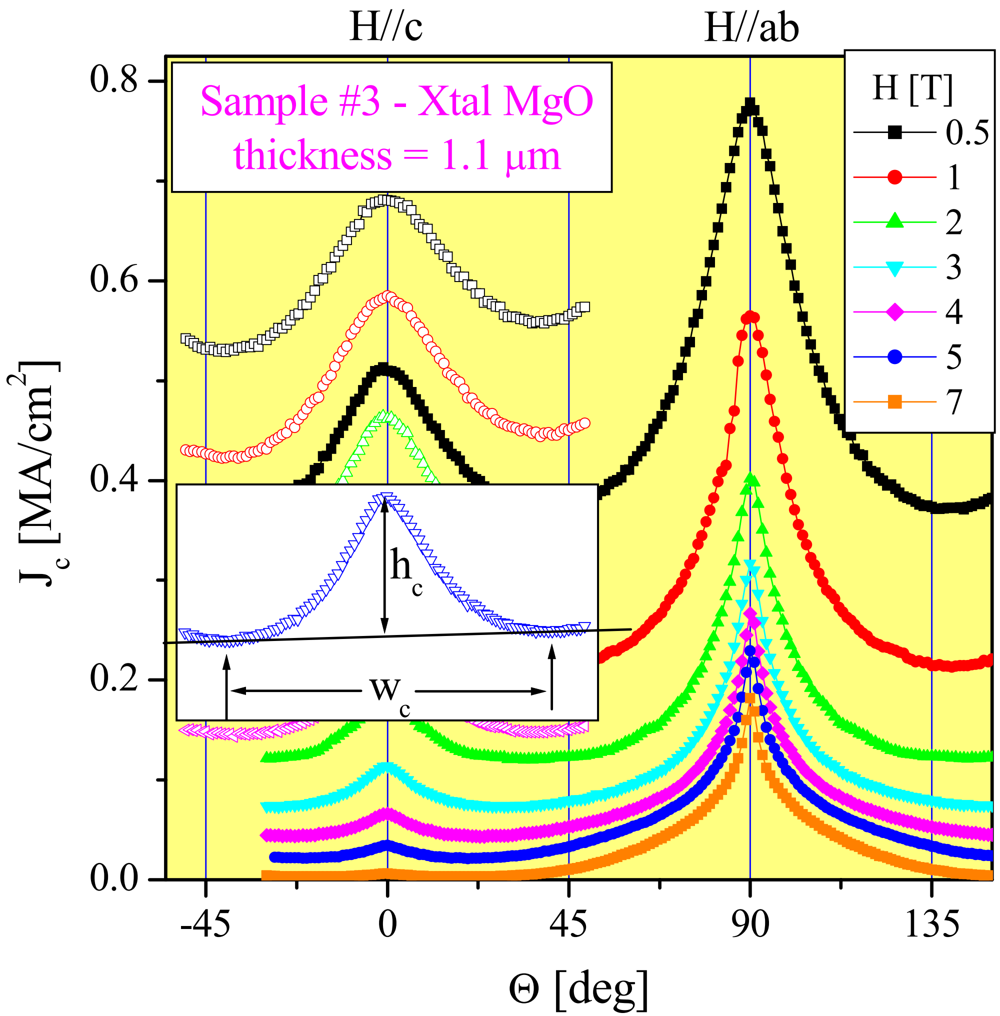
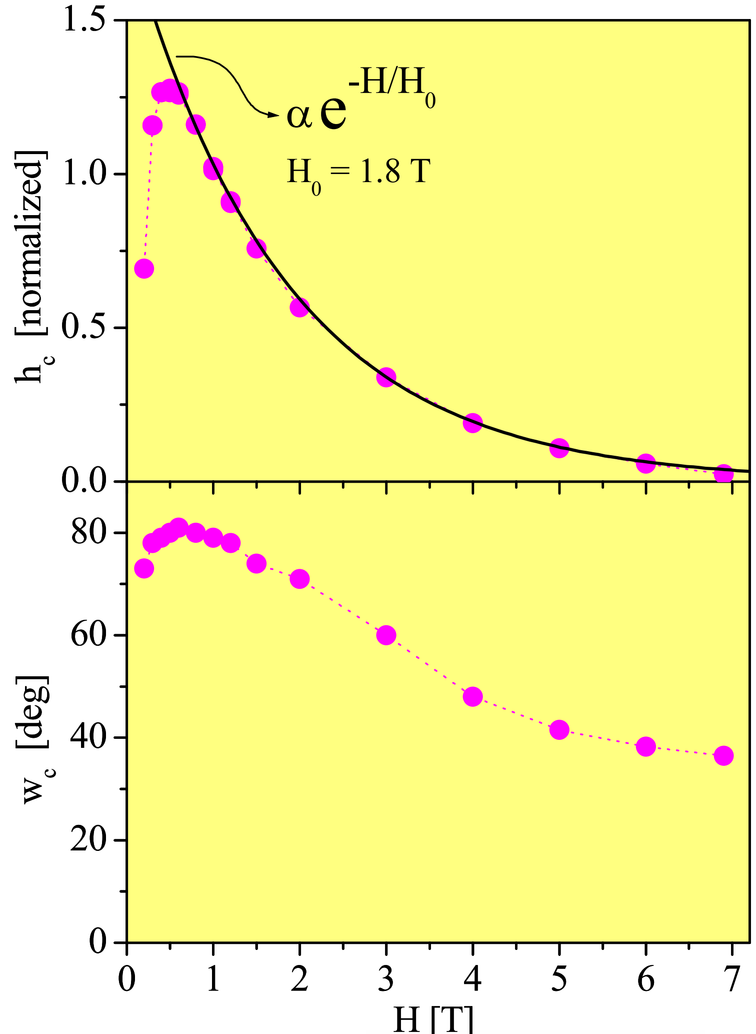


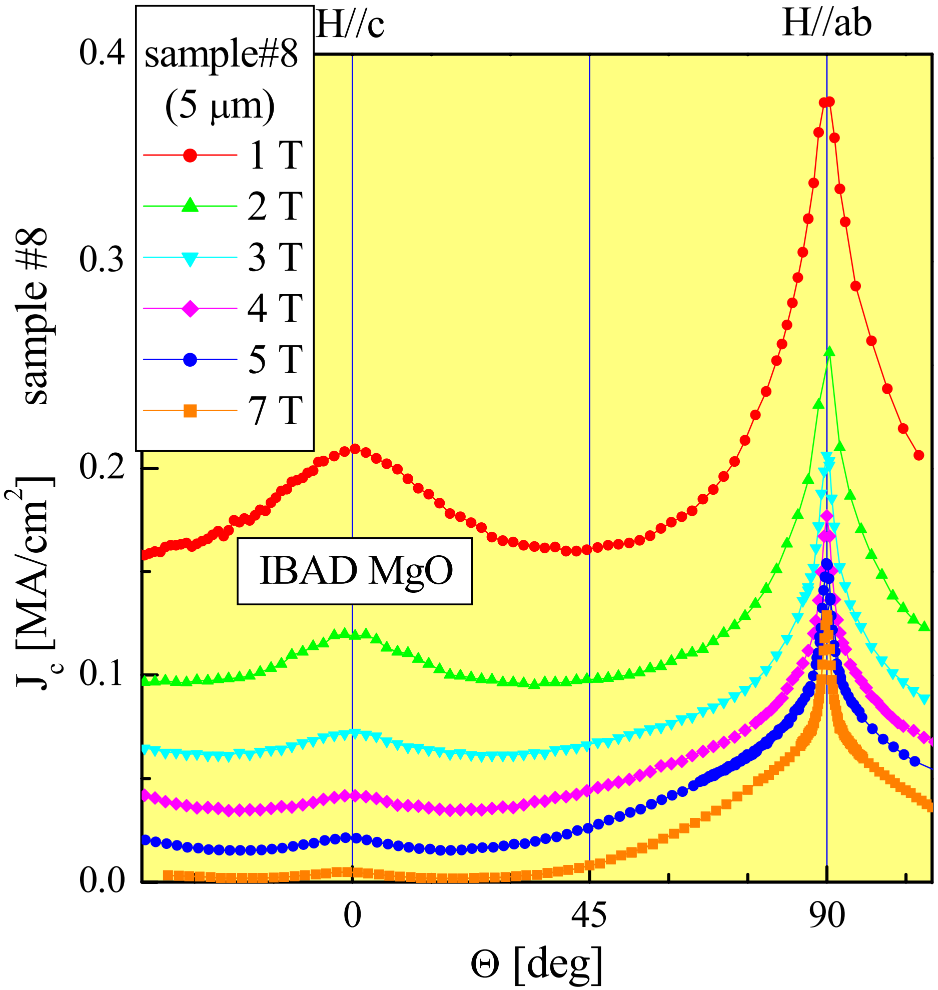


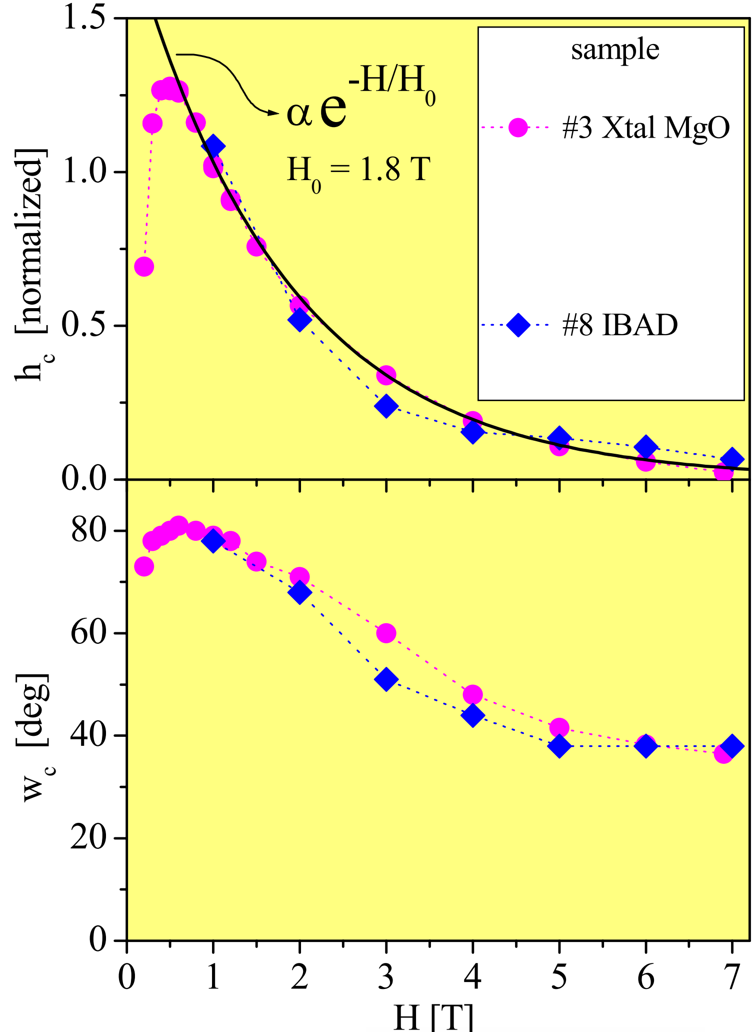
c axis peak: directional pinning by correlated disorder (linear or planar)



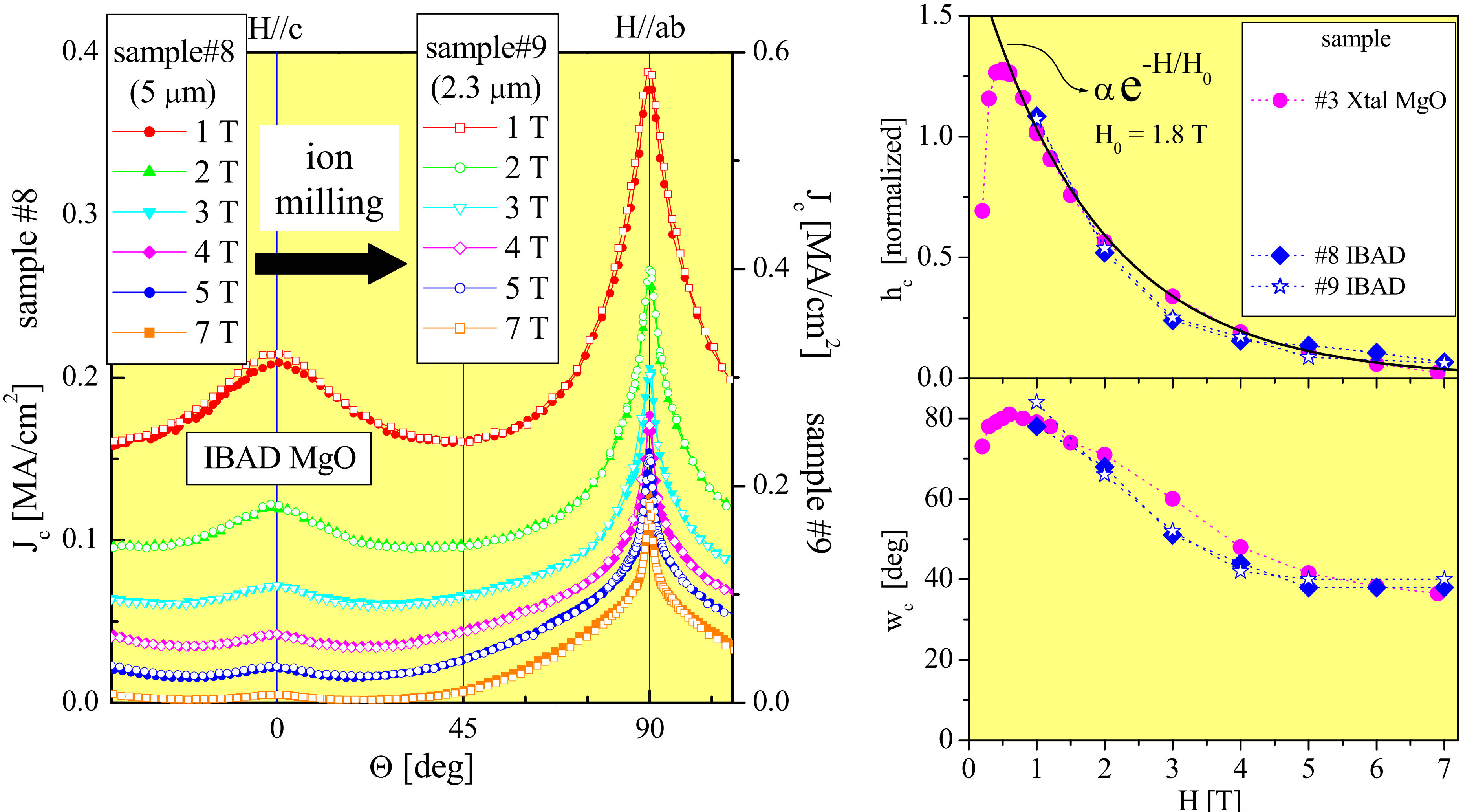


Field dependence of c axis peak for IBAD MgO samples





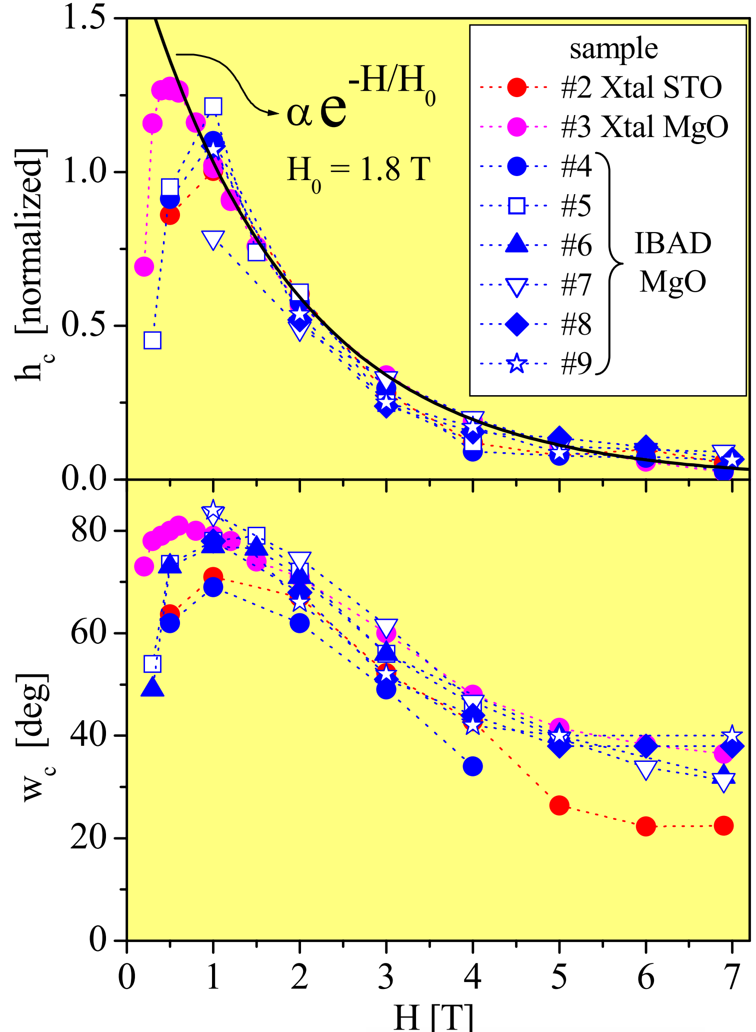
Field dependence of c axis peak for ion-milled IBAD MgO sample



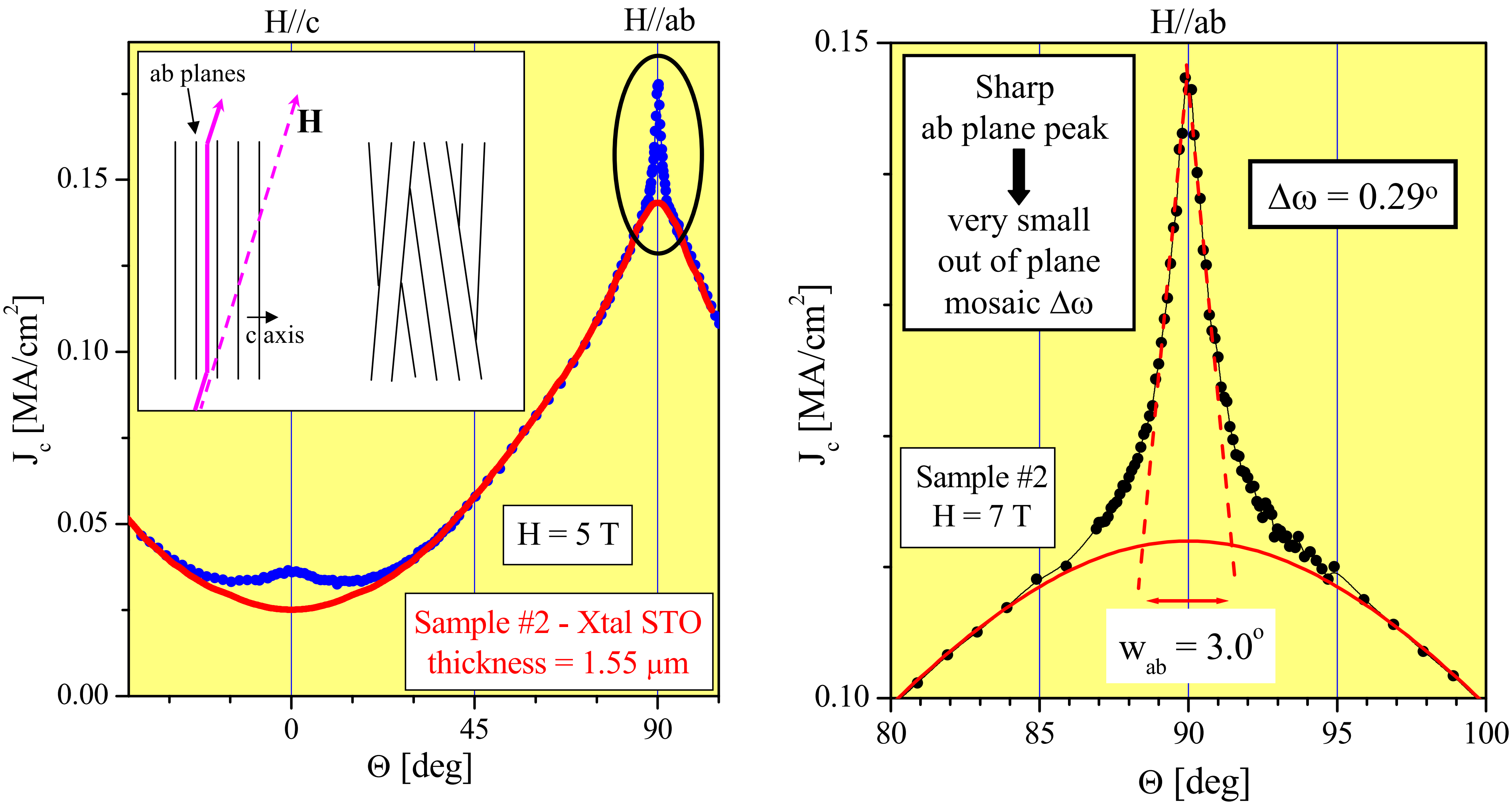
Field dependence of c axis peak for different samples

The height and width of the c axis peak have essentially the same field dependence for 8 films on STO and MgO single crystal and IBAD MgO templates, with thickness ranging from 1 to 5 μm, including one ion-milled sample

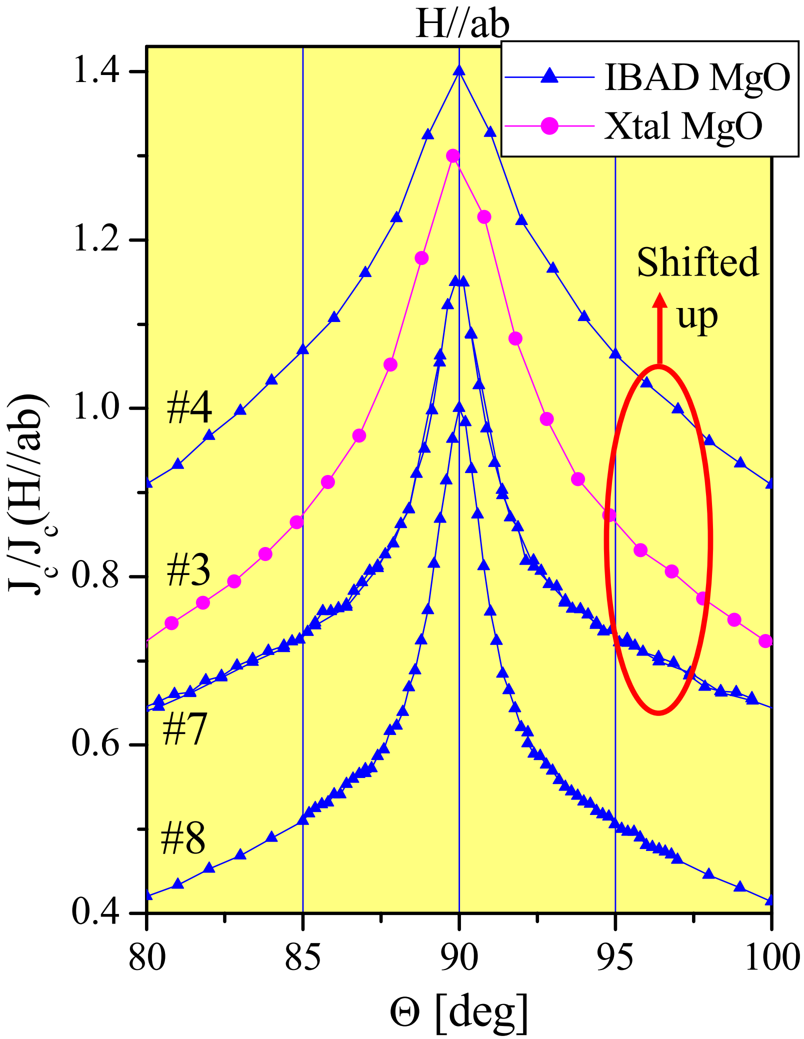
- The same type of correlated defects must be acting in all cases
- The difference in height indicates variations in defect density
- Crossover observed at H ~ 1 T



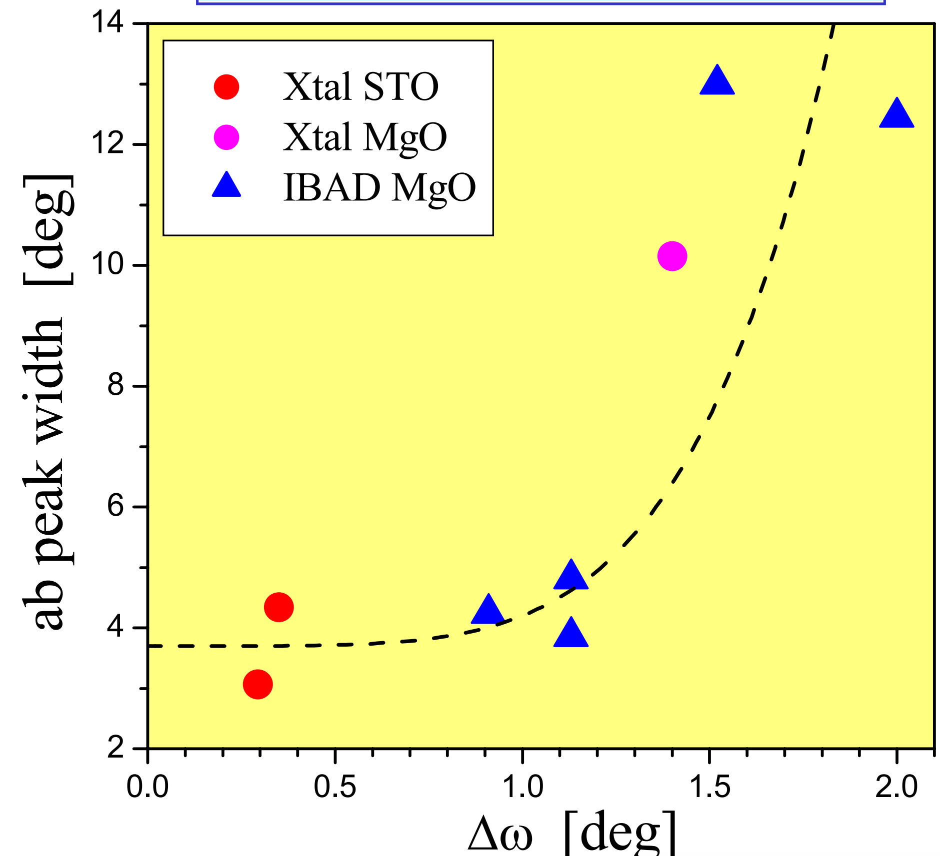
Intrinsic pinning peak at the ab planes



The intrinsic pinning peak is visible in all films



The peak sharpens as out-of-plane texture improves



Summary so far

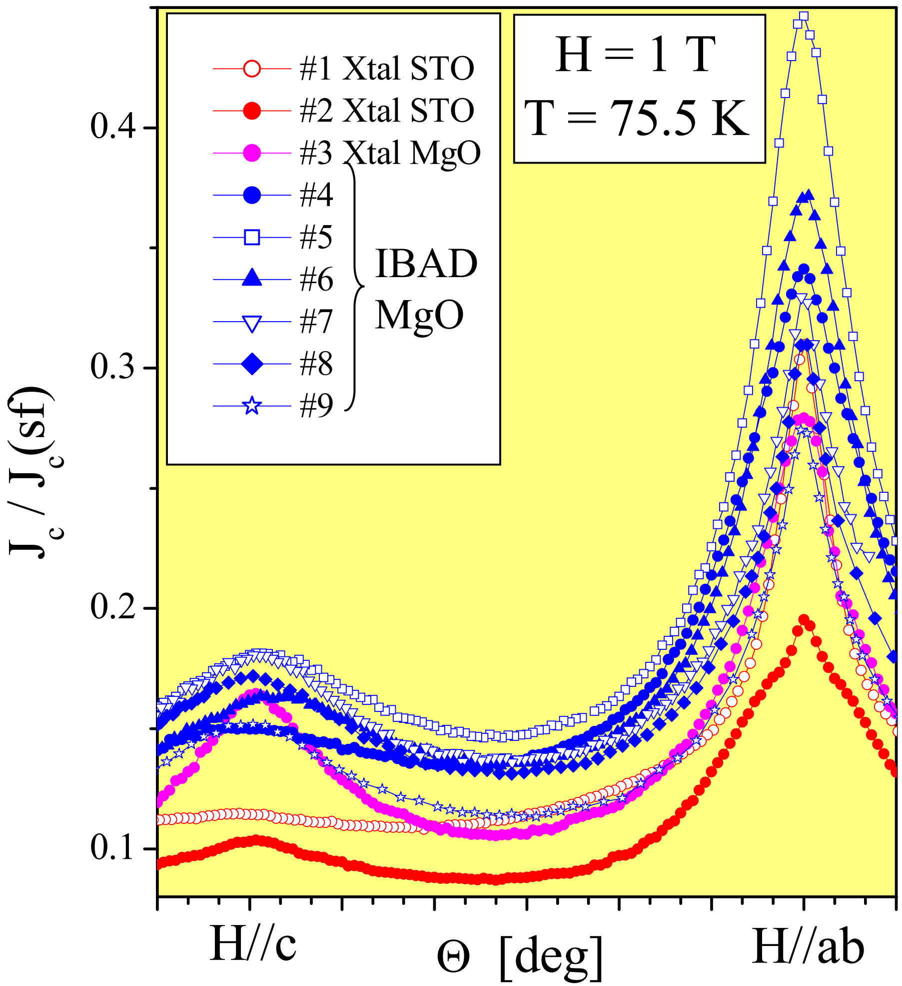
•Reproducibility among samples made by the same process is good.

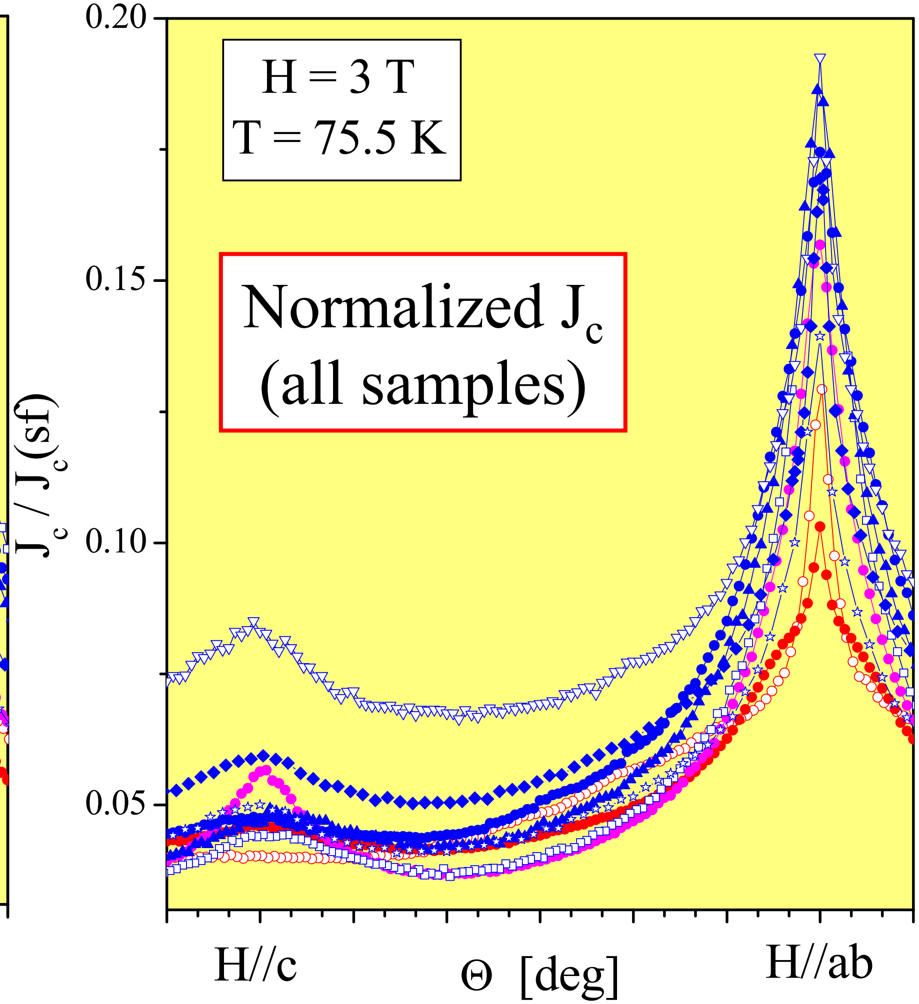
•Samples of different type have overall similar angular dependence.

•The main sources of vortex pinning and the various angular regimes were identified.

- •The angular dependence of the contribution of random defects to J_c can be described using an anisotropic scaling approach.
- •The c axis peak arising from correlated disorder such as twins and grain boundaries was characterized. Both the angular width and the normalized amplitude of the peak follow an universal field dependence for PLD YBCO.
- •An additional ab plane peak due to intrinsic pinning appeared in all measured samples. The peak sharpens as the out-of-plane texture of the film ($\Delta\omega$) decreases.

Comparison of $J_c(H,\Theta)$ for PLD YBCO films on IBAD MgO and on single crystal substrates





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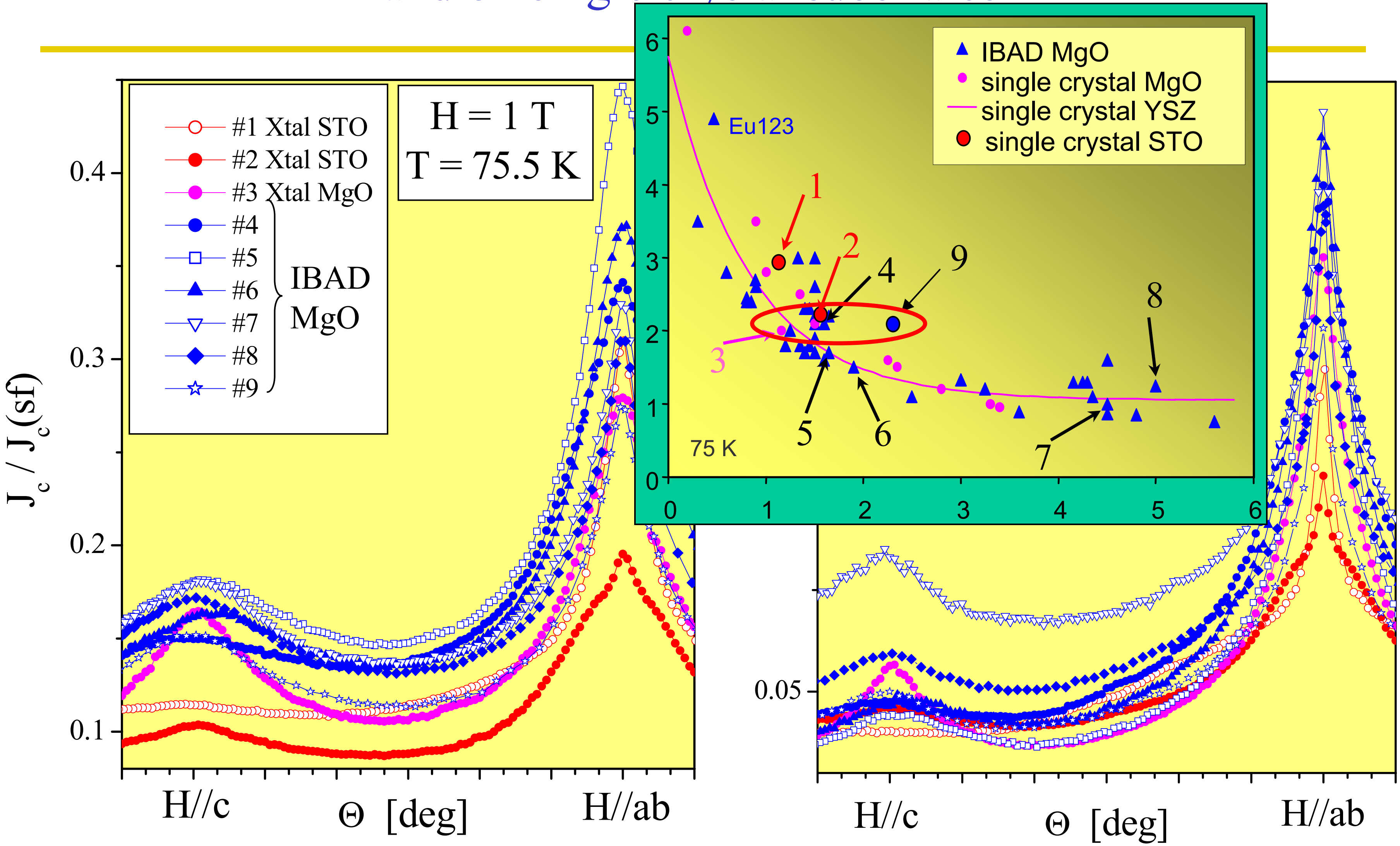

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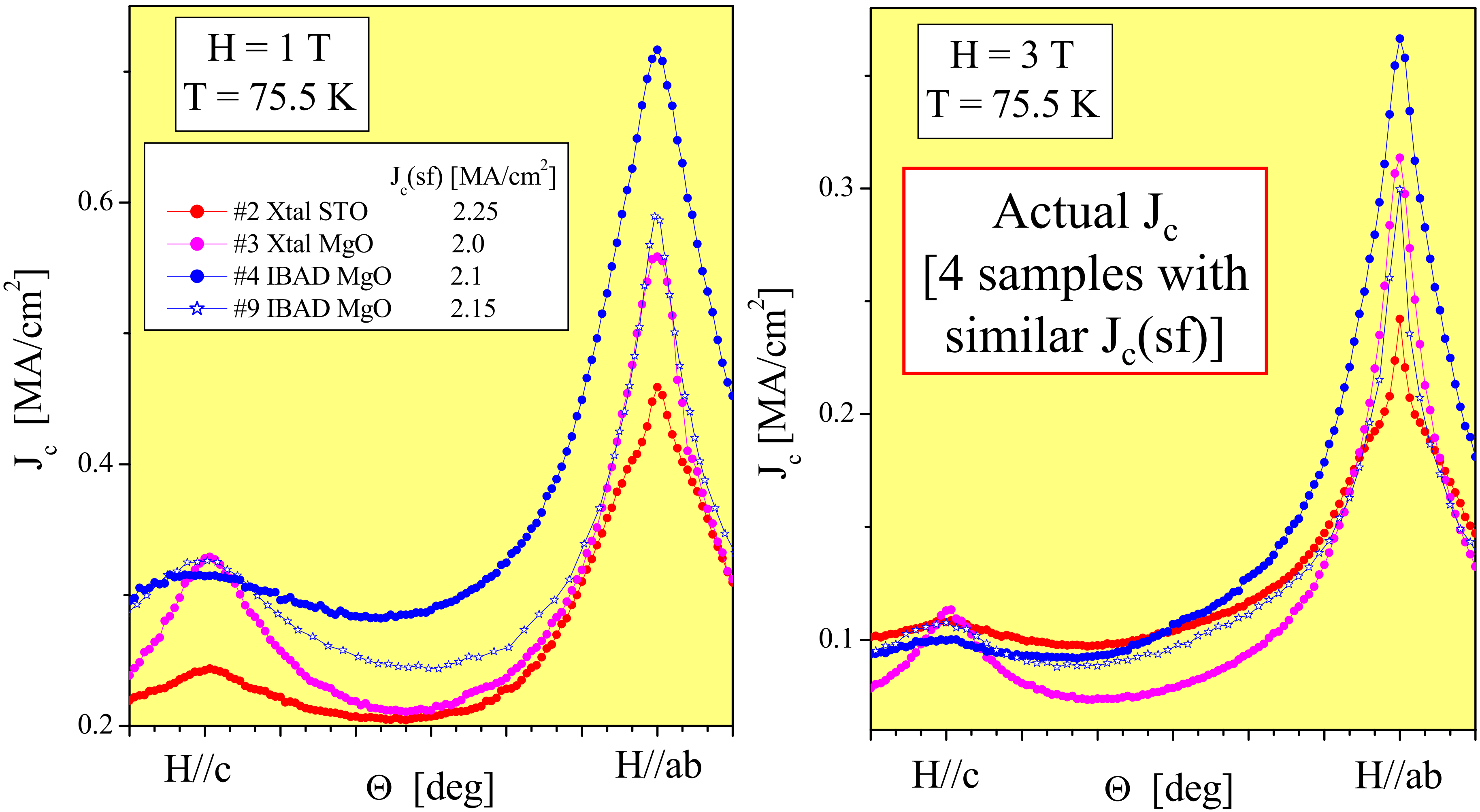

Conclusions

•The PLD YBCO / IBAD MgO coated conductors have HIGHER J_c than the films on single crystals over extensive ranges of magnetic field intensity and orientation. The extra pinning probably arises from:

- •Additional random defects (larger RBS reflectivity)
- •Additional c axis correlated defects:
  - • More screw dislocations at low-angle grain boundaries.
  - • Slightly higher in-plane mosaic $\Delta\phi$.
  - • Sub-grain structures.
- •Additional correlated structures parallel to the ab planes (higher out-of-plane $\Delta\omega$)

•There is room for further pinning improvement in CC through microstructural engineering.

•Pinning optimization will be application dependent.